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(54) Print head with water repellent coating

(57) A water-repellent coating (100) of a high wiping resistance to a wiper and capable of being formed by a simple process is a plated metal coating (106) which includes flat hard bodies (108) and fluoropolymer (104). The coating is formed around a nozzle of a nozzle which contains a removable resist.

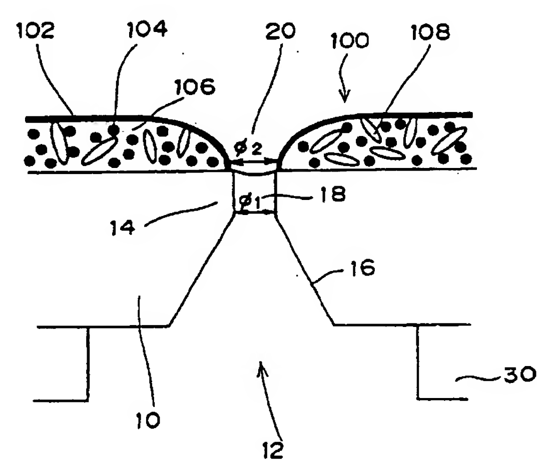

FIG. 1

EP 1 043 160 A1

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Description

[0001] The present invention relates to print heads having liquid jet nozzles, and, in particular, to a nozzle plate for an inkjet printer.

[0002] Those inkjet print heads using a piezo-electric element have recently become increasingly popular for their high energy-efficiency. This kind of inkjet print head typically comprises a piezo-electric element, one common ink chamber with ink supplied from outside and stored therein, a plurality of pressure chambers connected to the piezo-electric element and a nozzle plate connected to the pressure chambers so that a nozzle is associated with each pressure chamber. Each pressure chamber is connected via a corresponding ink feed path to the common ink chamber to receive ink from the common ink chamber. On increasing internal pressure by utilising a deformation of the piezo-electric element, ink is thereby jetted from the nozzle.

[0003] A water-repellent coating is typically formed around the nozzles on the surface of the nozzle plate opposite to the pressure chamber. The water-repellent coating has the following advantageous effects. Firstly, the water-repellent coating serves to stabilize the direction in which ink jetted from the nozzle travels. Without the water-repellent coating, ink ejected from the pressure chamber will adhere to the nozzle plate surface and will attract the next quantity of ink jetted and thereby bend the direction of travel of ink and prevent it from travelling in a desired direction. Secondly, the water-repellent coating serves to smooth a wiping process. After a printing operation has been completed, the inkjet head usually undergoes a backup process that eliminates din from the nozzle. In the backup process, a suction pump contacts the nozzle and sucks out dirt therein and, at the same time, ink in the nozzle adheres to the surface of the nozzle plate. Thus, a wiping process follows use of a wiper such as a rubber blade to wipe ink from the nozzle surface. Without the water-repellent coating, it would not be possible for the ink adhered onto the nozzle plate surface after the backup process to be successfully wiped off and it would remain on the nozzle plate surface. Consequently, the subsequently direction of travel of ink would be deflected and printing quality reduced due to impure or diluted coloring if the remaining ink is different in color from the subsequently delivered ink.

[0004] To combat the forgoing effects, it has been necessary for the inkjet head to be given a water-repellent coating. However, a conventional water-repellent coating has a fluoropolymer of high water repellency as a main ingredient. The fluoropolymer is soft and does not adhere well to a substrate, and thus is likely to develop flaws, abrasions or scratches as it is subjected to wiping and therefore, its anticipated water repellency cannot be continuously maintained. Accordingly, there is a need to provide a water-repellent coating that has a fluoropolymer as a main ingredient and is continuously usable about one hundred thousand times.

[0005] Conventionally, it has been proposed for example that a fluoropolymer is applied in sheet form and for a subsequent heating process to melt the fluoropolymer to cause it to adhere to the surface to which it has been applied, and form a coating of improved wiping resistance. Even with process, however, the coating formed, is soon worn out and its water repellency reduced. On the other hand, it has also been suggested to form a concave member around the liquid jet and simply avoid the need to provide a fluoropolymer coating around the nozzle which is scratched by friction. The process for providing this member, however, increases labour costs.

[0006] Accordingly, it is an object of the present invention to provide a print head having a novel and useful water-repellent coating and a method of providing the water-repellent coating in which the above disadvantages are eliminated.

[0007] According to one aspect of this invention, there is provided a print head comprising:

a nozzle plate having at least one nozzle which provides a jet of ink; and
a water-repellent coating which is formed in a plating process around said at least one nozzle with said nozzle plate acting as a substrate, and which coating comprises hard bodies and a fluoropolymer.

[0008] In a second aspect, this invention provides a method of forming a water-repellent coating on a nozzle plate for a print head comprising the steps of:

forming on the nozzle plate a resist so as to occupy and project from a nozzle of said nozzle plate;
forming on the nozzle plate a resist so as to occupy and project from a nozzle of said nozzle plate;
plating the nozzle plate around the resist with a water-repellent coating containing at least one hard body and a fluoropolymer; and
removing the resist.

[0009] Preferably, the plating procedure will be preceded by the formation of a strike coating on the substrate.

[0010] The water-repellent coating employed on a print head preferably includes hard bodies having a flat shape. The hard bodies are then less likely to be lost from the coating than spherically shaped ones and remain able to maintain wiping resistance for a long time. Preferably, a water-repellent coating includes hard bodies having a major axis of

1 µm or less in diameter. Such hard bodies of big particle diameter never prevent a nozzle plate surface from being smoothly wiped. Although various hard body materials can be used, it is preferably that they be boron nitride or boron carbide single crystals. These intrinsically have the advantage of a flat shape and require no additional process to deform them into a flat shape. The water-repellent coating may be provided in an electrolytic or electroless plating process which may, in principle be a simple conventional plating process.

[0011] By providing a printing device with a print head embodying this invention with an aforedescribed water-repellent coating, the water repellency of the fluoropolymer is available to act against liquid like ink, etc. jetted from the nozzle, with the hard bodies enhancing wiping resistance of the fluoropolymer.

[0012] The method of forming a water-repellent coating according to the second aspect of the invention is particularly suited to forming a water-repellent coating embodying this invention with the hard bodies protruding from the water-repellent coating surface because of the manner in which the water-repellent coating is formed on the nozzle plate. Subsequently, heating of the water-repellent coating can be carried out until its water repellency becomes enough to make a contact angle of ink containing 10% of alcohol of 60 degrees or more. In the heat treatment, the fluoropolymer melts and takes up the additive hard bodies.

[0013] For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

FIG. 1 is a schematic sectional view illustrating the application of a water-repellent coating in accordance with the present invention.
FIG. 2 is a schematic sectional view illustrating a variant of the water-repellent coating shown in FIG. 1, showing such coating after a predetermined period of use.
FIG. 3 is an enlarged view of a portion shown in a circle in FIG.2.
FIG. 4 is a schematic sectional view of a different applied water-repellent coating composition to that shown in Fig. 1 containing spherical hard bodies in contrast to the flat hard bodies of Fig. 1.
FIG. 5 is a schematic sectional view of the coating of Fig 4 showing a state in which the spherical hard bodies in FIG.4 have been worn down.
FIG. 6 shows the steps in a method of forming the water-repellent coating shown in FIG. 1.
FIG. 7 shows the steps in another method of forming the water-repellent coating shown in FIG. 1.
FIG. 8 is an exploded perspective view of a completed inkjet head.
FIG. 9 is a partially enlarged side view of an inkjet head.
FIG. 10 is a perspective overview of a printing device embodying the present invention.
FIG. 11A to 11C are photographs of the surface of print heads embodying this invention produced according to FIG. 7 and produced with different BN contents, as indicated, in the plating composition.

[0014] FIGs. 1 to 3 are schematic sectional views for explaining the composition of a water-repellent coating 100 embodying the present invention and how it performs, in use, the same reference numerals denoting like features in the respective figures.

[0015] The water-repellent coatings 100 and 100a are, for example, 1 to 2 µm thick and are formed around a nozzle 12 at the surface of a nozzle plate 10. FIG. 1 is an enlarged sectional view around a nozzle (hole) 12 appropriate to a print head 300 which will be described later (e.g. piezo-type inkjet head or a bubble jet-type inkjet head). The nozzles 12 each have a straight portion 14 and a taper portion 16, and are present in a number corresponding to a predetermined resolution. The nozzle 12 does not necessarily include both of the straight portion 14 and the taper portion 16 but may include only one of them. A portion defined by the straight portion 14 is an opening portion 18 of the nozzle 12 wherein a meniscus 20 of ink is formed. The nozzle plate 10 is connected to a pressure chamber plate 30, and the pressure chamber plate 30 is provided with an ink chamber which will be described later.

[0016] The water-repellent coatings 100 and 100a comprise a fluoropolymer-containing coating 102 made up of fluoropolymer particles 104, a nickel matrix 106 and flat hard bodies 108. The water-repellent coating 100 shown in FIG. 1 is different from the water-repellent coating 100a shown in FIG. 2 where flat hard bodies 108 partially protrude from the water-repellent coating 102.

[0017] The water-repellent coatings 100 and 100a are characteristically formed on the nozzle plate 10 which serves as a substrate. This invention does not adopt such a method in which the water-repellent coating and the nozzle plate 10 are applied in sequence to a substrate and then the substrate is removed because, in this latter this method, the hard bodies 108 are unable to protrude from the fluoropolymer coating 102 as shown in FIG. 2. A projecting hard body 108 as shown in FIG. 2 acts to prevent the water-repellent coating from being scratched as a result of friction as of a wiping blade (wiper) passed over it and makes it possible to maintain ink-water repellency for a long period.

[0018] Examples of fluoropolymers for the coating 102 and the particles 104, are tetrafluoroethylene resins, tetrafluoroethylene-hexafluoropropylene copolymerization resins, trifluorochloroethylene resins, fluorovinylidene resins, fluorovinyl resins, PTFE, FEP, ETFE, PFA, PCTFE and PVDF used either singly or in the form of a mixture of two or

more of them. Their average particle diameters should preferably be less than 150 µm and in particular range from 0.05 to 20 µm. In addition to the above fluoropolymer particles, as needed, other inorganic or organic precipitation polymer particulates may be incorporated.

[0019] The nickel base 106 enables a coating to be produced by plating to improve adhesion. Other than nickel, there may be employed copper, silver, zinc, tin, cobalt and such nickel alloys as a nickel-cobalt alloy, a nickel-phosphorus alloy and a nickel-boron alloy, etc. The plated coating can be formed, for instance, by using an electrolytic plating solution or electroless plating solution in which PFA is suspended. The electrolytic plating solution from which the metal plating coating is to be deposited may be selected from an electrolytic nickel platingsolution such as the Watts bath, a chloride-rich bath, a nickel sulfamate bath and a nickel borofluoride bath; an electrolytic cobalt plating solution such as a cobalt sulfate bath and a cobalt chloride bath; an electrolytic copper plating solution such as a copper sulfate bath and a copper borofluoride bath; an electrolytic lead/tin plating solution such as a lead sulfate bath, a tin sulfate bath and a lead borofluoride bath. It is however preferable to employ a sulfamic acid bath having a sulfamic acid ion content of more than 0.5 mol, more desirably more than 0.8 mol especially in the light of the ability of such ions to enhance deposition rate and resist agitation. The electroless plating solutions may be selected, additionally, from an electroless nickel plating solution, an electroless cobalt plating solution and an electroless copper plating solution, etc. using a boron compound such as a hypophosphate and a dimethyl borazone, etc. as a reducing agent.

[0020] The hard bodies 108 have a greater hardness than a fluoropolymer and a flat shape. The hard bodies 108 should preferably be as water-repellent and wiping-resistant as possible, and have as low a coefficient of friction as possible. Even though the hard body 108 has low water repellency, a heat treatment as will be described later melts the fluoropolymer, covers the hard bodies 108, and thereby maintains the water repellency. The hard bodies 108 are added so as to promote the wiping resistance of the fluoropolymer with respect to the wiper. Their flat shape enhances their anchoring in the plating coaling. Thus, suppose that spherical hard bodies 208 (e.g. having more than 1µm in diameter) are dispersed in the water-repellent coating 200 (e.g. of about 1µm in thickness), as shown in FIG. 4, if the water-repellent coating 200 has its surface wiped by a wiper 5, the spherical hard bodies 208 will not only have more than half of their diameter embedded in the water-repellent coating 200, but will be forced out, as shown in FIG. 5, so that the wiping resistance of the water-repellent coating is reduced to the level of a water-repellent coating having no hard bodies 208. In FIG. 5, a surface mark left by a hard body 208 is indicated with 209.

[0021] Usable as a source of hard bodies 108, for example, are BN (boron nitride), boron carbide, silicon carbide, titanium carbide, tungsten carbide, graphite fluoride, alumina, glass and ceramics, etc. Boron nitride and boron carbide are suitable for use in the water-repellent coating of this invention in that they are available as single crystals which do not possess a spherical crystal structure (the boron nitride crystal is flat). Particularly, boron nitride, which is used for reducing the friction of bearings, is suitable for improving sliding properties of the electroless nickel coating and increasing strength of the fluoropolymer coating 108. When alumina, glass, ceramics particles are used, they should be deformed into a flat shape. BN may be added in an amount of for example, 5g/l or more, preferably 10g/l, more preferably 20g/l.

[0022] Since the additive hard bodies 108 are less water-repellent than the fluoropolymer, the water-repellent surface should be formed as much as possible of the fluoropolymer. Therefore, it is necessary to increase the water-repellent portion of liquid contact surface by heating and melting the fluoropolymer after its application.

[0023] Referring now to FIG. 6, a description will be given of a method of manufacturing a nozzle plate with a water-repellent coating as shown in FIGs. 1 and 2. FIG. 6 is a flow diagram for exemplifying a method of producing the water-repellent coating 100 shown in FIG. 1 or the water-repellent coating 100a shown in FIG. 2. First, as shown in FIG. 6(A), is a nozzle plate substrate 10 of a stainless steel (SUS316) of 100 µm to 300 µm thickness which is processed by stamping, etching, electrical discharge machining and laser machining, etc. and is provided with a nozzle 12. To illustrate, assume that a conical nozzle 12 is made by stamping the straight portion 1440 µm thick and 20 µm long, and producing a taper portion 16 having a taper angle of 20°. Nozzle plate surface 22 is roughly ground to remove burrs left by working, although the burrs are not completely removed.

[0024] Next, as shown in FIG. 6(B), a corrosion-resistant polymer resin as a resist is used to fill the nozzle 12. A photosensitive liquid resist is usable as a resin material in anticipation of its subsequent removal and its machinability. Use may be made of a curing acrylic resin as a dry film resist (DFR) 24. The DFR 24 becomes a viscous liquid by applying sufficient heat and readily fills the nozzle 12. Further, in terms of its removal, DFR is water soluble and may be easily removed with aqueous alkali solution.

[0025] The nozzle plate surface 22 is immersed in an etching solution for stainless steel and etched to achieve the result shown in FIG. 6(C). On the nozzle plate surface 22 there exist burrs left by the processing or rough working of the nozzle 12. These are easily be removed by the etching process. This makes it possible to omit a final finishing grinding step in processing the nozzle plate 10, and enables a cost-reduction to be achieved. In addition, a chemical grinding method can be used to reduce mechanical stress applied to the nozzle substrate 10 and may improve processing accuracy. The etching depth is 10 µm and the length of straight portion 14 is 10 µm.

[0026] Thereafter, there take place in turn water washing, an electrolytic degreasing, a water washing, an acid

washing and plating with a water-repellent Ni coating 100 on the nozzle plate surface 22 by Ni plating with other components suspended therein - see FIG. 6(D). The water-repellent coating 100 produced has a thickness not exceeding the height of the protruding DFR 24. Then, the nozzle plate 10 is immersed in an aqueous alkali solution, to wash away the DFR 24 and the result of FIG. 6(E), is achieved, namely a nozzle plate 10 with a water-repellent coating 100. When materials which are difficult to etch, such as ceramics, glass, etc. are used for the nozzle plate 10, the grinding process (FIG. 6(C)) may be replaced by a physical method using a sandblast. In that event, a sandblast-resistant DFR 24 that includes a polyurethane resin rather than an acrylic resin (e.g. BF series made by Tokyo Ohka Kogyo Co., Ltd.) may be employed. The physical grinding method can be used with a nozzle plate substrate 10 made of metal.

[0027] By following the following the above procedures, the water-repellent coating 100 produced on the nozzle plate surface 22 by Ni deposition plating is formed wound projected portion of DFR 24, which prevents the deposited material entering nozzle 12 and thus maintains the size accuracy of the nozzle 12 and the water-repellent coating 100. For example, in FIG. 1, the water-repellent coating 100 is formed so as not to fall through the nozzle by making its diameter $Ø_2$ within a 3 % range of the diameter $Ø_1$ of opening 18. This 3 % difference is for the purpose of having the opening in the water-repellent coating 100 and the opening 18 in the nozzle plate in alignment. This arrangement can prevent a deflection of ink dots, stabilise direction of ink travel and provide high quality images.

[0028] Referring next to FIG. 7, a description will be given of another method of manufacturing the nozzle plate 10 having the water-repellent coating 100. The process shown in FIG. 7 includes a variation of the process step of FIG. 6(C) and those that follow, and it is to be noted that the process indicated in FIG 7(A) follows the process indicated in FIG. 6(B). As shown in FIG. 7(A), a liquid resist or a DFR coating 26 capable of alkaline development and removal is formed on the nozzle plate surface 22, and then the exposure and development with a mask pattern eliminate coatings around opening 18 on the nozzle plate surface 22. Next, as shown in FIG. 7(B), the nozzle plate substrate 10 is immersed in an etching solution and the surface adjacent the opening in the coating 26 is etched. The etching depth can be adjusted by altering etching conditions. By adjusting the depth, the length of the straight portion 14 and the projecting amount of the DFR 24 are adjusted.

[0029] As shown in FIG. 7(C), the coating 26 is removed with strongly alkaline solution. In this case, the DFR 24 is an alkaline-resistant resist, and is thus not eliminated and remains. After that, a water washing, an acid washing, an electrolytic degreasing, a water washing and Ni plating take place. As shown in FIG. 7(D), Ni deposition takes place on the nozzle plate surface 22 and the water-repellent coating 100 is formed. The coating thickness is so adjusted that it does not exceed the projecting amount of the DFR 24. Thereafter, as shown in FIG. 7(E), the DFR 24 is removed and eliminated using a solution development-type resist removal solution.

[0030] The above manufacturing method can also provide a nozzle plate 10 having an accurately sized water-repellent coating 100, as in FIG. 6. This method, particularly as it uses DFR 24 as a resist member, only needs a heating process and an exposure process may be omitted. The method required one step less, thereby reducing manufacturing costs.

[0031] The manufacture of a water-repellent coating 100 shown in FIG. 1 or a water-repellent coating 100a shown in FIG. 2 will now be described. First, in order to form a water-repellent coating only on the surface of the nozzle plate 10 by plating, other surface portions are masked so as not to have the coating adhere. In this step, the nozzle plate 10, acting as a substrate, is laminated at the side at which a pressure chamber 30 is formed with an alkaline development-type dry film resist, for example the product α-450 made by Tokyo Ohka Kogyo Co., Ltd., under conditions of 120°C C, 2.5 kgf/cm, 0.5m/min. This allows the dry film to enter the taper portion 16 and the straight portion 14 of the nozzle 12. Moreover, the film resist flows out of ink jet openings of the nozzle to cover a portion around the edge of the nozzle openings which has a width of 1 µm. The film resist is hardened by a double-sided exposure.

[0032] For forming a plating acting as a water-repellent coating containing single crystal BN (boron nitride), a fluoropolymer-containing Ni plating solution (made by Hikifune Co., Ltd.) has BN with longitudinal particle size of 1 µm or smaller (particles of more than 1 µm crushed to this size) added in an amount of 20g/l to the plating solution which is used to provide a water-repellent plating on the nozzle plate 10 masked as described above.

[0033] For carrying out deposition on the nozzle plate 10, which is made of stainless steel (SUS430), the plate is immersed in 10% hydrochloric acid for three minutes, washed in water to remove oxidized coating and is then strike plated with Ni to improve its subsequent plating adhesion.

[0034] The specification for the Ni strike plating is as follows.

(1)	Bath composition	
	nickel chloride ($NiCl_2 . 6H_2O$)	220 g/l
	hydrochloric acid (HCl 35%)	45 g/l

(continued)

(2)	Temperature	room temperature
(3)	Electrode titanium mesh basket (150 x 30 x 250 mm) containing electrolytic nickel (Ø 1B x 10 mm)	
(4)	Current density	2A/dm2

[0035] After carrying out strike plating for one minute using this strike Ni plating solution, the nozzle substrate is immersed in a water-washing bath and immediately thereafter is subjected to a water-repellent plating process. The specification of the water-repellent plating is as follows.

(1)	Bath composition	
	nickel sulfamate	420 to 480 g/l
	nickel chloride	40 to 50 g/l
	boric acid	30 to 40 g/l
	PTFE	40 to 50 g/l
	BN	20 g/1
	pH	4.0 to 4.4
(2)	Temperature	42° C
(3)	Electrode	
	titanium mesh basket (150 x 30 x 250 mm) electrolytic nickel (Ø 1 B x 10 mm) diaphragm	
(4)	Current density	2 A/dm^2

[0036] The nozzle substrate is plated for three minutes using the water-repellent plating solution. After washing in water, it is immersed in a NaOH (3 wt%) solution, the film resist is removed, and then, after water washing and drying processes, the applied coating is subjected to a heating process at 350° C for thirty minutes. The plated coating produced has BN particles scattered therein and an appearance as shown in FIG 11 for plating compositions having the above-described BN content of 20g/L and also BN contents of 5g/L and 10g/L. In each case the convex portion of the BN particles prevents the surface as produced from being scratched even tough a fluoropolymer coating existing thereon is scratched by friction and abrasion of a wiper (rubber blade). In this way, a water-repellent effect can be maintained.

[0037] Referring next to FIGs. 8 and 9, a description will be given of an inkjet head 300 to whose nozzle plate the present invention is applied. FIG. 8 is an exploded view of the completed inkjet head 300 and FIG. 9 is a enlarged partially side view of the inkjet head 300. As seen from FIG. 8, the inkjet head 300 of the present invention comprises a pressure chamber plate 310, a piezo-electric element 320, a nozzle plate 330, a resin film 340 and a protective layer 350. The nozzle plate 330 corresponds to the nozzle plate 10 shown in FIG. 1 and the pressure chamber plate 310 corresponds to the pressure chamber plate 30 shown in FIG. 1. The pressure chamber plate 310, the resin film 340 and the protective layer 350 are aligned with each other at a nozzle connection surface 360, that is a surface to which a surface 330a of the nozzle plate 330 is connected. In other words, the front surface 310a of the pressure chamber plate 310, a front surface 340a of the resin film 340 and a front surface 350a of the protective layer 350 form the flat nozzle connection surface 360.

[0038] The pressure-chamber plate 310 has the desired number (four in FIG. 8 for description purposes) of pressure chambers 312 and ink introduction channels 314 and a common ink chamber 316 in an approximately rectangular parallelepipedic glass plate. Each pressure chamber 312 receives and accommodates ink, and jets the ink from a nozzle 332 connected to an opening 312a as its internal pressure increases. The internal pressure changes as the piezo-electric block 321 just under the pressure chamber 312 deforms, as will be described later. The pressure chamber 312 is formed as an approximately rectangular parallelepipedic space by a concave groove on the pressure chamber plate 310 and the elastically deformable resin film 340. The common ink chamber 316 supplies ink to each pressure chamber 312 via the corresponding ink introduction channel 314. The bottom of the common ink chamber 316 is defined by the resin film 340 which absorbs sudden internal pressure changes, connection to an ink feed device (not shown) taking

place at a side surface 310b of the pressure chamber plate 310. The common ink chamber 316 supplies the necessary amount of ink to the pressure chamber 312 via the ink introduction channel 314 when the pressure chamber 312 returns to its original state after the chamber 312 contracts, receives pressure and jets ink.

[0039] The resin film 340 defines one surface of each of the pressure chambers 312, the common ink chamber 316 and each of the ink introduction channels 314, and serves to transmit a deformation of each piezo-electric block 321, which will be described later, to the corresponding pressure chamber 312 and acts to prevent ink in the pressure chamber 312 from penetrating into grooves 323 in the piezo-electric element 320. The resin film 340 is, for example, approximately 16 μm thick and may be a Gpa adhesive. The resin film 340, may be replaced by an elastic thin metal film.

[0040] The piezo-electric element 320 has a layered structure having a plurality (four in FIG. 1 for description purposes) of piezo-electric blocks 321 which are divided by parallel grooves 323 which extend from front surface 320a to rear surface 320b. Internal electrodes 322 and 324 are provided between layers of piezo-electric blocks 321, and the internal electrode 322 is connected to an external electrode 326 and the internal electrode 324 is connected to an external electrode 328. FIG. 8 shows only one external electrode 328 for illustration purposes but one is present for each piezo-electric block 321. As shown in FIG. 9, an active area 325 is a portion where internal electrodes 322 and 324 overlap each other in direction A, and each piezo-electric block 321 deforms in the active area 325. The length of each active area 325 is adjustable depending upon the pressure to be applied to the pressure chamber 312. Since the active area 325 is spaced at a predetermined distance from the nozzle connection surface 360, even when the piezo-electric blocks 321 deform, such deformation does not affect the adhesion between the piezo-electric element 320 and the protective layer 350 at the nozzle connection surface 360.

[0041] The external electrode 326 is an electrode layer that is vapour deposited onto the entire front surface 320a of the piezo-electric element 320, and is an external electrode of a type commonly used for all piezo-electric blocks 321. The external electrode 326 is grounded. In contrast, the external electrode 328, which is provided on the rear surface 320b of the piezo-electric element 320, is however a vapour deposited layer which is not formed over the entire rear surface 320b and is provided only on portions each corresponding to a piezo-electric block 321. The external electrode normally 328 has zero potential, but may apply a positive voltage to the internal electrode 324 as will be described hereinafter.

[0042] Due to its having such a structure, each piezo-electric block 321 of the piezo-electric element 320 does not deform when no voltage is applied to the external electrode 328, since both potentials of the internal electrodes 322 and 324 remain zero. On the other hand, when a voltage is applied from the external electrode 328, each piezo-electric block 321 may deform in the direction A (longitudinal direction) in FIG. 8, independently of the other piezo-electric blocks 321. In other words, the direction A is the polarisation direction of the piezo-electric blocks 321. When the supply of a potential to the external electrode 328 stops, that is, when the piezo-electric element 320 is discharged, the corresponding piezo-electric block 321 returns to the original state.

[0043] The piezo-electric elements 320 for this purpose may be made from a plurality of green sheets 327. Each green sheet 327 is a blend of a solvent and a ceramic powder, etc., kneaded into a paste and then formed by a doctor blade into a thin film having a thickness of about 50 μm.

[0044] With these green sheets, an internal electrode 322 pattern is printed and formed onto one surface of each of the three green sheets, an internal electrode pattern 324 is printed and formed onto one surface of each of another three green sheets, and no internal electrode is formed onto the remaining sheets. Each of the internal electrodes 322 and 324 is printed from a blend of an alloy powder of silver and palladium and a solvent, with the resulting paste being applied in pattern formation.

[0045] Then, the three sheets which include an internal electrode 322 and the three sheets which including an internal electrode 324 (and any further such sheets) are alternatively arranged, and then stuck together. As a result, the layered structure of the piezo-electric element 320 as shown in FIG. 9 is arrived at. Green sheets that include neither of the internal electrode 322 or 324 are stuck to the bottom (in FIG. 9) of the piezo-electric element 320 and form a base part. These layered green sheets are sintered. Then, a diamond cutter working from the front surface 320a to the rear surface 320b is applied to at least six sheet depth as a partial cut, whereby a plurality of the piezo-electric blocks 321 divided by the grooves 323 is formed. Lastly, the external electrodes 326 and 328 are formed by vacuum vapour deposition at the front surface 320a and the rear surface 320b. It is possible to form the grooves 323 before sintering. The completed piezo-electric element 320 is submitted to a characteristic test by applying a voltage to the external electrodes 326 and 328, and malfunctioning elements 320 are discarded.

[0046] The inkjet head 300 shown in FIG. 8 further comprises the protective layer 350. The protective layer has useful effects as will be explained later, but this protective layer may be dispensed with.

[0047] The protective layer 350 is a thermosetting epoxy adhesive member having an approximately rectangular parallelepipedic shape with a thickness of about 50 μm, and is connected via a surface 350b to the front surface 320a of the piezo-electric element 320 (external electrode 326). The materials for the protective layer 350, however, are not limited to such epoxy adhesives. For example, an epoxy filler, an acrylic resin or a polyethylene resin can be used for the protective layer 350. The protective layer 350 in the actual inkjet head 300 does not have a rectangular parallelepi-

pedic shape in the strict sense of the term, and the interface between the protective layer 350 and the piezo-electric element 320 is not as clear or simple as represented in FIGs. 8 and 9 by the external electrode 326 and the surface 350b. While hot, protective layer 350 partially penetrates the piezo-electric element 320 via the grooves 323 before solidifying. Accordingly, it is preferable that the protective layer 350 is made of insulating material so as to prevent a short circuiting of the internal electrodes 322 and 324. The protective layer 350 of this embodiment is applied to the piezo-electric element 320 (external electrode 326) all over the front surface 320a, but may, if necessary, be applied only to part of this surface.

[0048] The protective layer 350 spaces the piezo-electric element 320 by about 50 μm from the nozzle connection surface 360. If ink leaks from the pressure chamber 12 and penetrates into the piezo-electric element 320, the ink would penetrate into the piezo-electric element 320 mainly along the nozzle connection surface 360. However, the protective layer 350 spaces from the nozzle connection surface 360 the piezo-electric element which has been conventionally located on the nozzle connection surface 360, and thereby prevents the ink from penetrating into the piezo-electric element 320 and short-circuiting the internal electrodes 322 and 324.

[0049] Moreover, the protective layer 350 shields the grooves 323. If ink were to leak and penetrate into the piezo-electric element 320, the ink would penetrate mainly from an opening 312a of the pressure chamber 312, running along the nozzle connection surface 360, through the grooves 323 into the piezo-electric element 320. However, the protective layer 350 blocks off the grooves 323 from the nozzle connection surface 360, and thereby prevents the ink from penetrating into the groove 323 from somewhere in the neighborhood of the front surface 320a of the piezo-electric element 320 and short-circuiting the internal electrodes 322 and 324.

[0050] In addition, the protective layer 350 also has the effect of protecting the piezo-electric element 320 from damage in a polishing process for forming the nozzle connection surface 320a which is one of various steps in the manufacture of the inkjet head. Consequently, the polishing process never causes any layer removal, cracking and chipping-off of the piezo-electric element 320. The external electrode is never cut off. Furthermore, the pressure chamber plate 310, which is made of glass, is rather strong, and enables such a high polishing speed as to shorten the polishing time down to about one-fifth in comparison with conventional manufacturing methods.

[0051] The nozzle plate 330 is made of metal, e.g. stainless steel. Each nozzle 332 may be formed, as described above with reference to FIG. 6, with a punch carrying pin or the like, preferably into a conical shape (or otherwise showing a tapering section) running from the front surface 330b toward the rear surface 330a of the nozzle plate 330. One of the reasons why the pressure chamber plate 310 and the nozzle plate 330 are not formed as one is the need to produce such conically shaped nozzles 332 while the nozzle plate 330 is adhered to the pressure chamber plate 310. In this embodiment, each nozzle 332 is about 80 μm in diameter at the rear surface 330a and about 25 to 35 μm at the front surface 330b. The present invention is also applicable to an inkjet head that has nozzles thereof formed, for example, above the pressure chamber plate 310 shown in FIG. 8, unlike the inkjet head 300.

[0052] On the surface (front surface) 330b of the nozzle plate 330, at least around the nozzles 332, is formed the water-repellent coating 100. Of course, the water-repellent coating 100 may be formed all over the front surface 330b. The water-repellent coating serves to stabilize wiping operations, which will be described later, and to provide a high quality image. It is to be understood that the water-repellent coating should be located differently in relation to the nozzles when the nozzles of the inkjet head are formed, for example, above the pressure chamber plate 310 shown in FIG. 8.

[0053] In the inkjet head 300, each external electrode 328 independently applies a voltage to the internal electrode 324 of the piezo-electric block 321, and each piezo-electric block 321 independently deforms in the direction A in FIG. 1, bending the resin film 340 in the direction A and compressing the corresponding pressure chamber 312. This compression results in jetting of ink from the pressure chamber 321 through the corresponding nozzle 332. When the application of a potential to the external electrode 328 stops, the resin film 340 and the piezo-electric block 321 return to the original states by discharging. At that time, the internal pressure of the pressure chamber 312 reduces and ink is supplied from the common ink chamber 316 through the ink introduction channel 314 to the pressure chamber 312.

[0054] Although this embodiment uses the piezo-electric element 320 that deforms in the longitudinal direction, another embodiment may use a piezo-electric element that deforms in the lateral direction. Further, the present invention is not limited to a piezo-type inkjet head employing a piezo-electric element but is applicable to a bubble-type inkjet head.

[0055] Referring next to FIG. 10, a description will be given of an inkjet printer 400 provided with the inkjet head 300 of the present invention. In this drawing, reference numerals are given terminal digits matching those in Figs. 8 and 9 for the like parts, and a duplicate description of like parts will be omitted. FIG. 10 schematically illustrates a color inkjet printer 400 to which an inkjet head 300 embodying the present invention is applied. A platen 414 is rotatably provided in a housing 410 of the recording device 400.

[0056] In a printing operation, the platen 412 is driven so as to rotate intermittently by a driving motor 414 and recording paper P is fed at a predetermined feed pitch in the arrow direction W. A guide rod 416 is provided in the housing 416 of the recording device parallel to and above the platen 412.

[0057] A carriage 418 is mounted to an endless drive belt 420 that is driven by the driving motor 422 as it undergoes reciprocating motion in scanning along the platen 412.

[0058] The carriage 412 is mounted by a black print head 424 and a color print head 426. The color printing head 426 may comprises three parts. The black printing head 424 is provided with a replaceable black ink cartridge 428, and the color printing head 426 is provided with replaceable color ink cartridges 430, 432 and 434. The inkjet head 300 of the present invention can be used with print heads 424 and 426.

[0059] Needless to say, the black ink tank 428 accommodates black ink and the color ink tanks 430, 432 and 434 accommodate yellow ink, cyan ink and magenta ink respectively.

[0060] While the carriage 418 reciprocates along the platen 412, the black print head 424 and the color print head 426 are driven according to image data received from a word processor or a personal computer and predetermined characters, images and the like are recorded on recording paper P. When the recording operation is suspended, the carriage 418 is returned to its home position and this home position is provided with a nozzle maintenance mechanism (or backup unit) 436.

[0061] The nozzle maintenance mechanism 436 is provided with a movable suction cap (not shown) and a suction pump (not shown) connected to the movable suction cap. When the recording heads 224 and 226 are placed at the home position, the suction cap is attached to the nozzle plate of each recording head and the nozzle of the nozzle plate is subjected to a suction. This mechanism prevents the nozzle holes from being blocked. Then, a wiping unit (also not shown) wipes the nozzle plate 330b with a wiper, with the water-repellent coating 100 helping ink on the nozzle plate surface 330b be wiped off completely, and the hard bodies 108 in the water-repellent coating 100 preventing the water-repellent coating from being destroyed or otherwise harmed.

[0062] In summary, the water-repellent coating employed in accordance with the invention maintains the water repellency of its fluoropolymer well to provide a high quality image, and its hard bodies enhancing the wiping resistance of the fluoropolymer guarantees continuous provision of a high quality image. If the water-repellent coating contains flat hard bodies, it is particularly less susceptible to friction or likely to be lost from the coating compared with a spherical hard bodies, and therefore can retain its wiping resistance for a long time. When the flat bodies have a big particle diameter, the nozzle plate surface will nevertheless always be smoothly wiped. Boron nitride and boron carbide hard bodies are preferable and are easily obtainable. Such water-repellent coatings as can be easily formed without the need to use any special plating process.

[0063] The preferred method of forming the water-repellent coating as set forth herein enables the hard bodies to protrude from the water-repellent coating surface. In particular, by having the fluoropolymer melt in a heat treatment, sufficient water repellency can be obtained on the surface of the intrinsically low water-repellent hard bodies.

Claims

1. A print head comprising:

    a nozzle plate having at least one nozzle which provides a jet of ink; and
    a water-repellent coating which is formed in a plating process around said at least one nozzle with said nozzle plate acting as a substrate, and which coating comprises hard bodies and a fluoropolymer.

2. A print head according to claim 1 wherein said hard bodies have a flat shape.

3. A print head according to claim 1 or 2, wherein the major axis of a said hard body does not exceed 1 μm diameter.

4. A print head according to claim 1, 2 or 3, wherein said hard bodies are constituted by boron nitride single crystals.

5. A print head according to claim 1, 2 or 3, wherein said hard bodies are constituted by boron carbide single crystals.

6. A print head according to any preceding claim 1 wherein said water repellent coating has been formed in an electrolytic plating process.

7. A print head according to claim 1 wherein said water repellent coating has been formed in an electroless plating process.

8. A printing device comprising:

    a print head according to any preceding claim; and
    a driving device which drives said print head.

9. A method of forming a water-repellent coating on a nozzle plate for a print head comprising the steps of:

forming on the nozzle plate a resist so as to occupy and project from a nozzle of said nozzle plate;
plating the nozzle plate around the resist with a water-repellent coating containing at least one hard body and a fluoropolymer; and
removing the resist.

10. A method of forming a water-repellent coating according to claim 9, comprising the step of providing a strike coating round the resist before carrying out the plating.

11. A method of forming a water-repellent coating according to claim 9 or 10, further comprising the step of heating said water-repellent coating until its water repellency is sufficient to make a contact angle of ink containing 10% of alcohol which is 60 degrees or more.

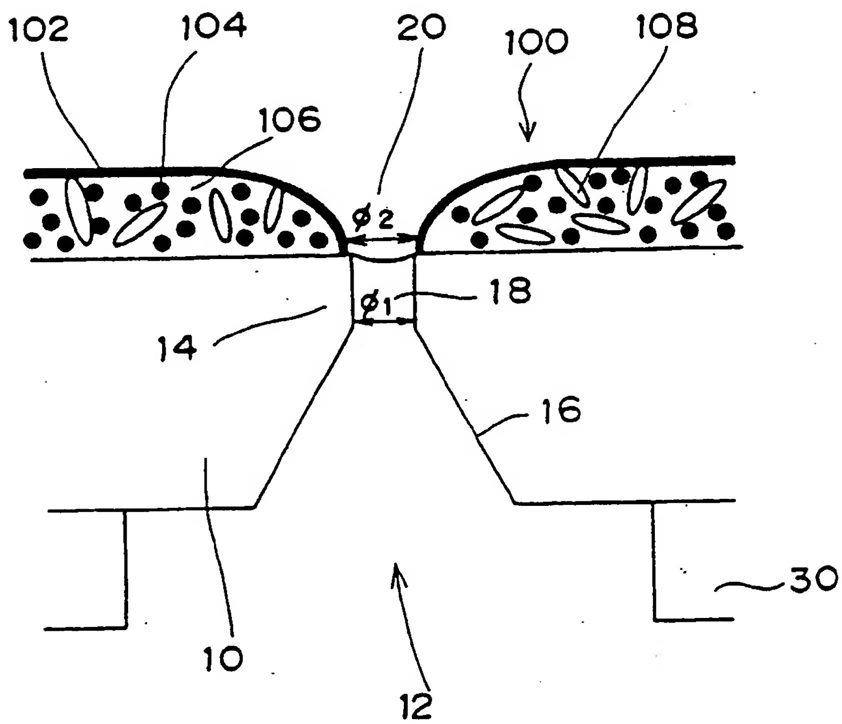


FIG. 1

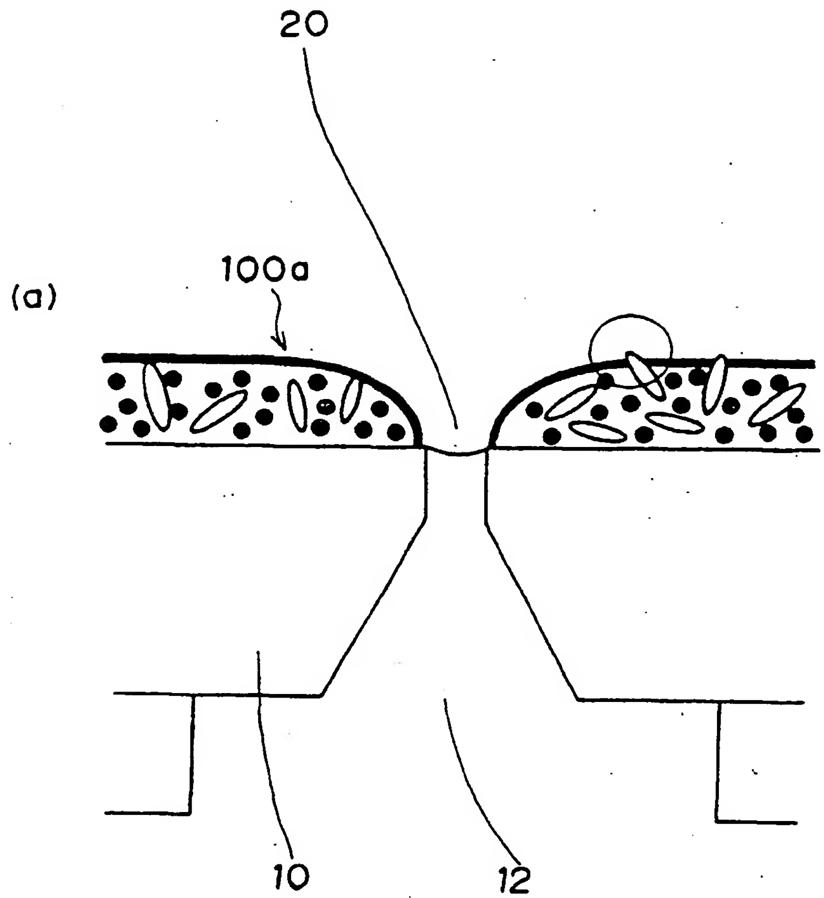


FIG. 2

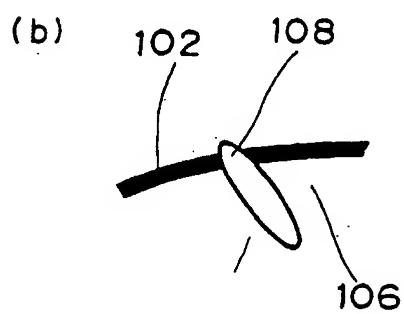


FIG. 3

(a)

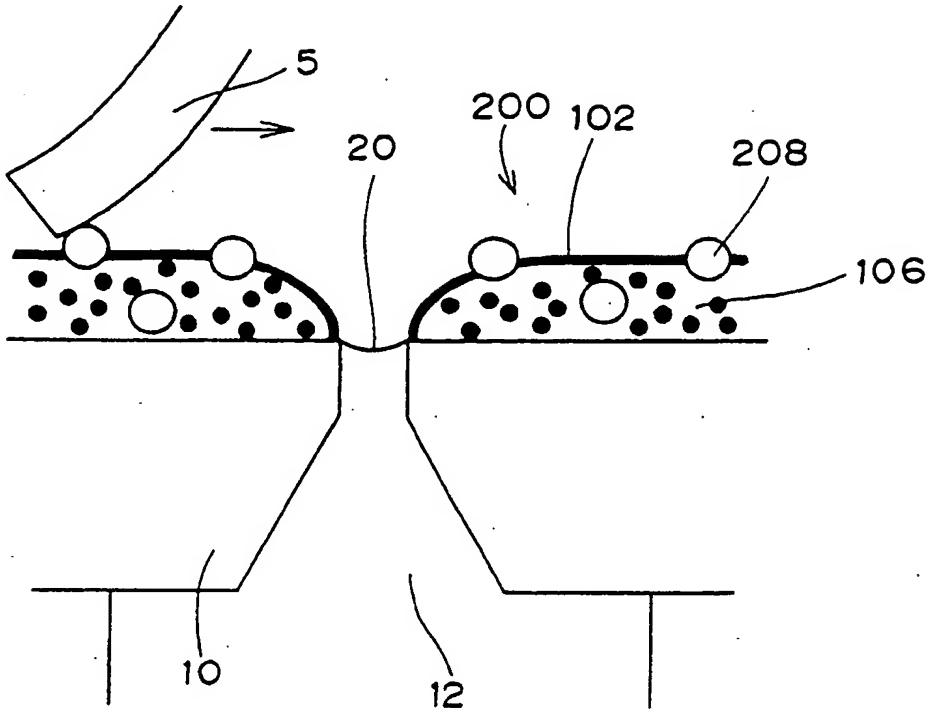


FIG. 4

(b)

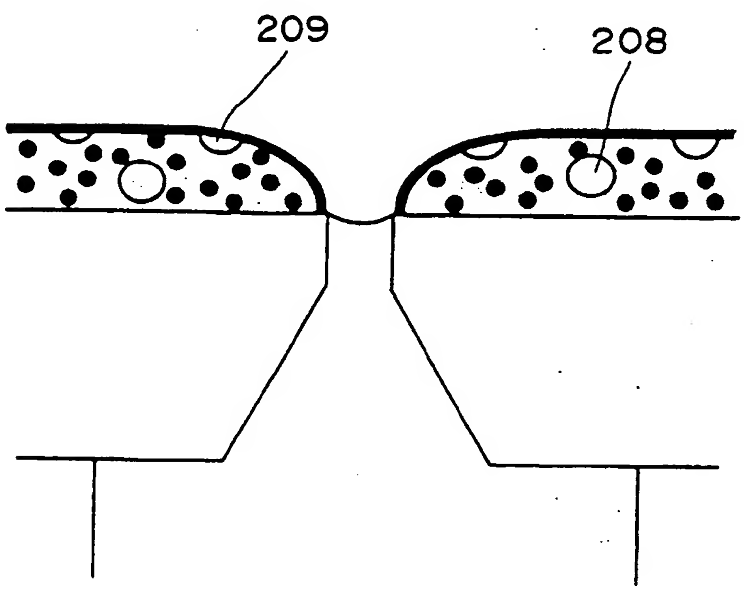


FIG. 5

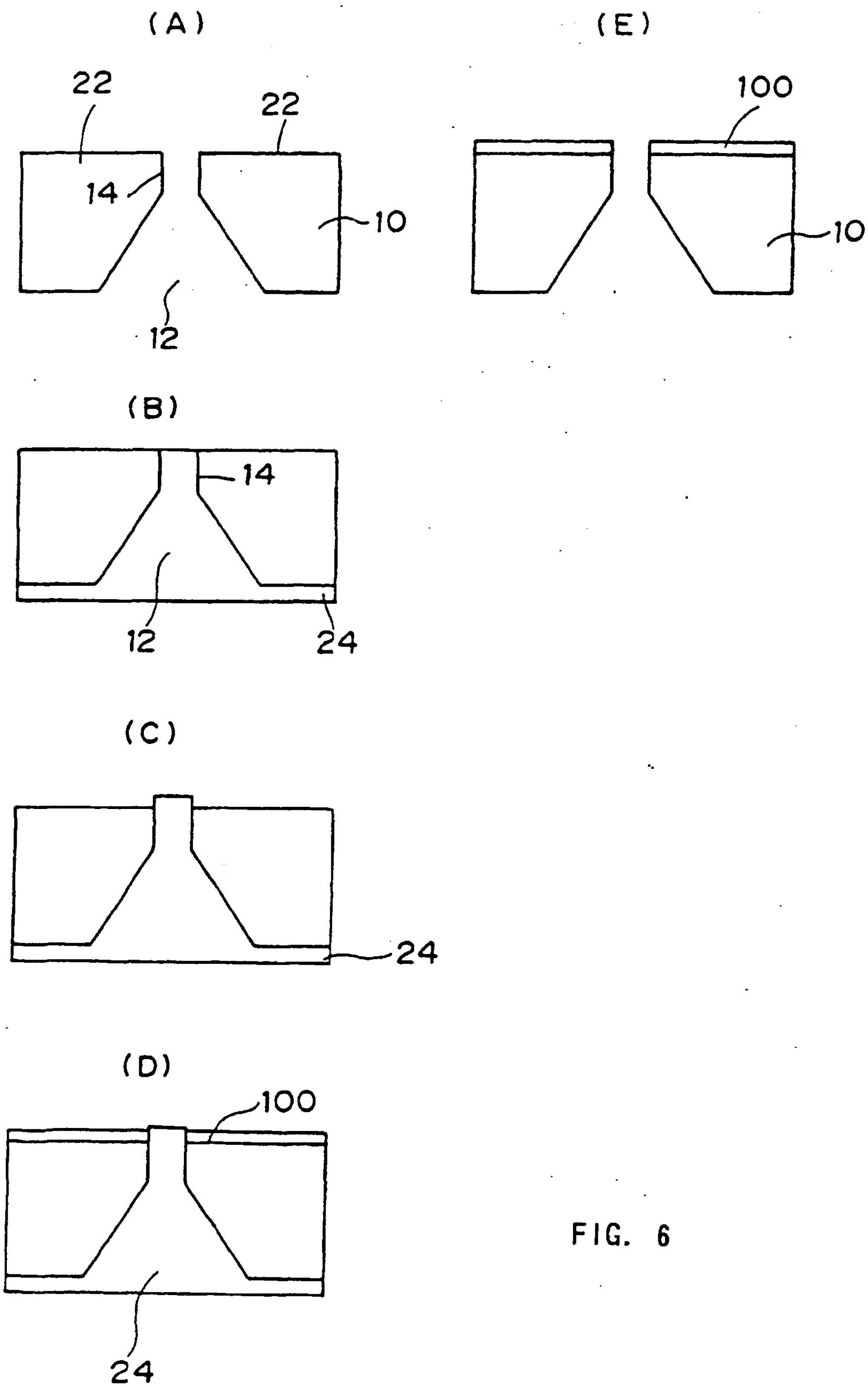


FIG. 6

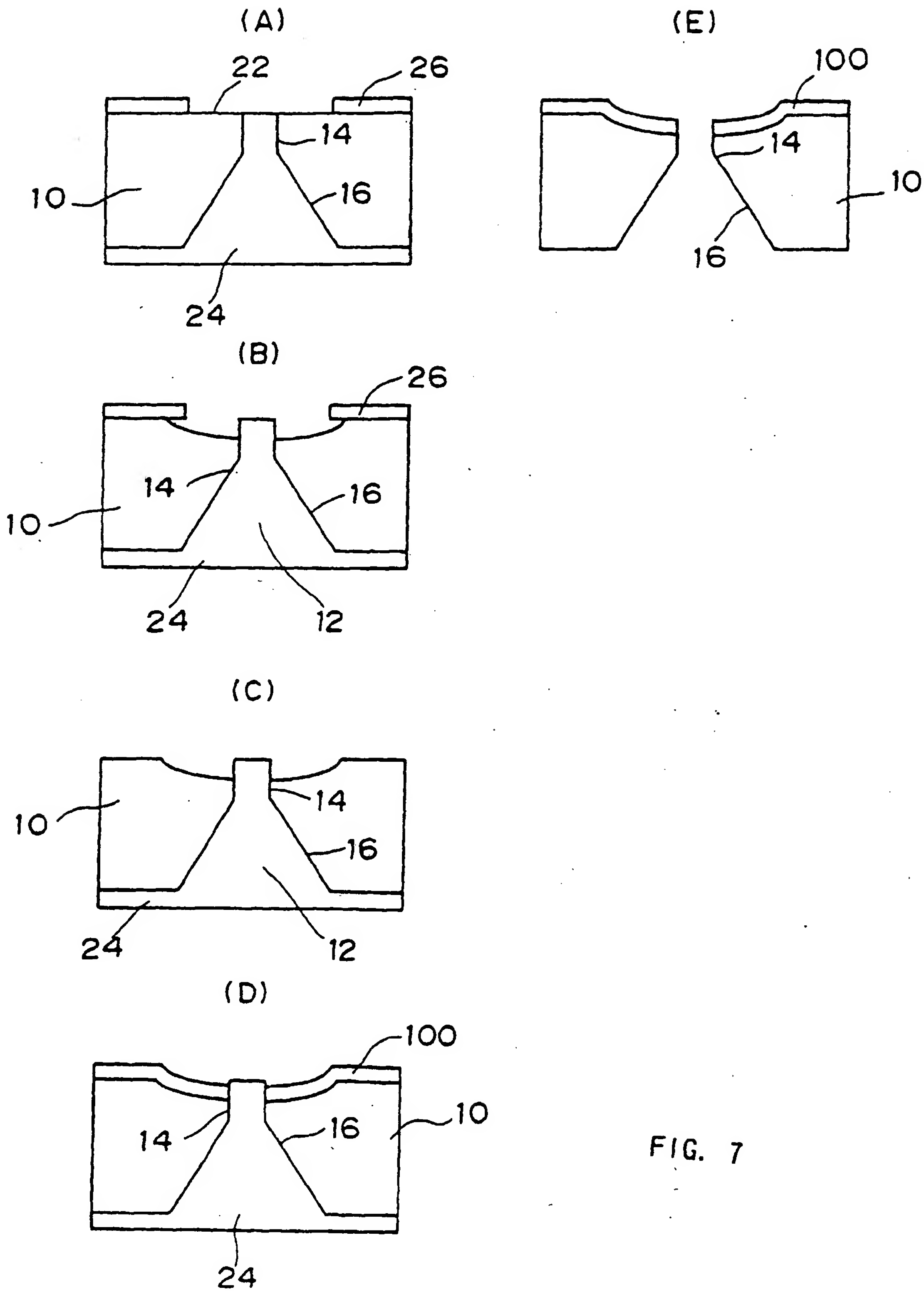
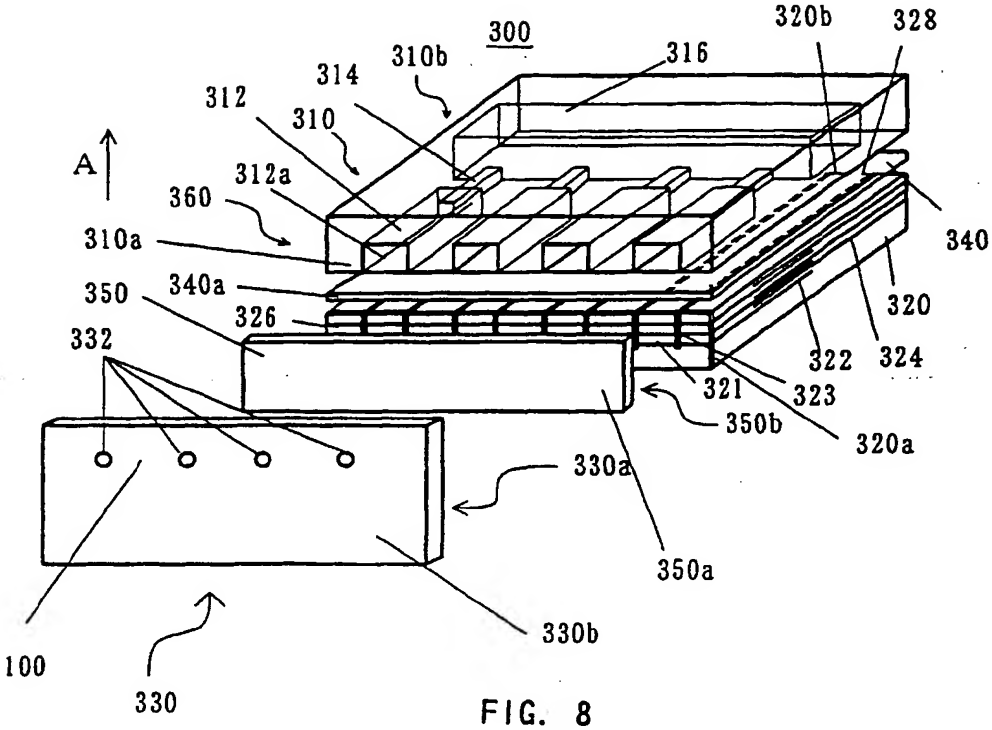

(A)
22
26
14
10
16
24
(B)
26
14
16
10
24
12
(C)
14
10
16
24
12
(D)
100
14
16
10
24
(E)
100
14
10
16

FIG. 7


300
310b
316
320b
328
314
312
310
A
312a
360
310a
340
340a
350
326
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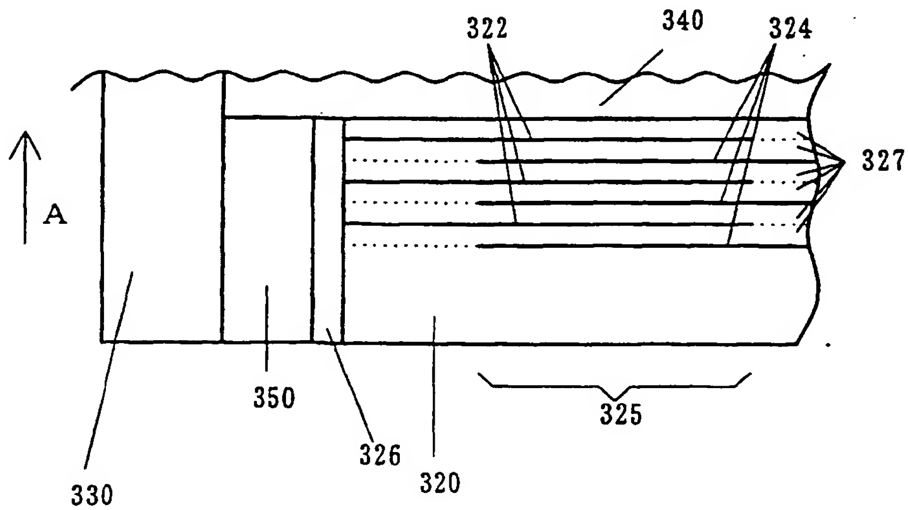
332
322
324
321
323
350b
320a
330a
350a
330b
100
330

FIG. 8


322
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A
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325
326
320
330

FIG. 9

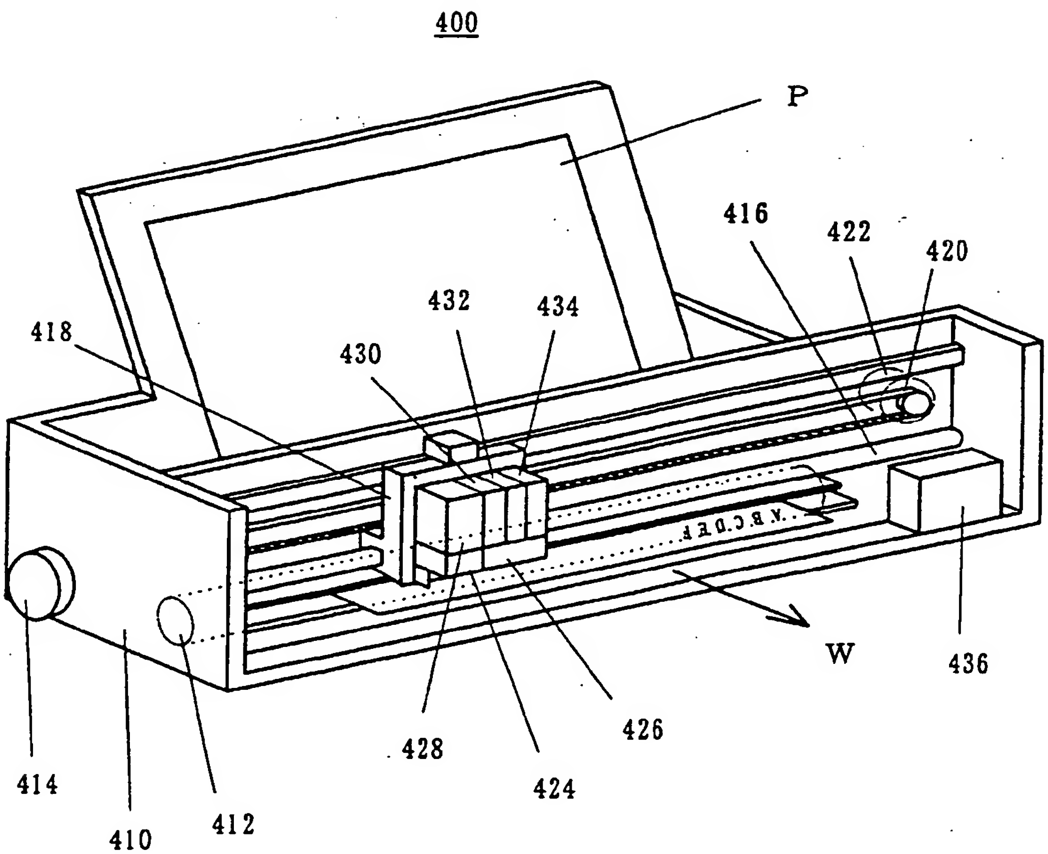
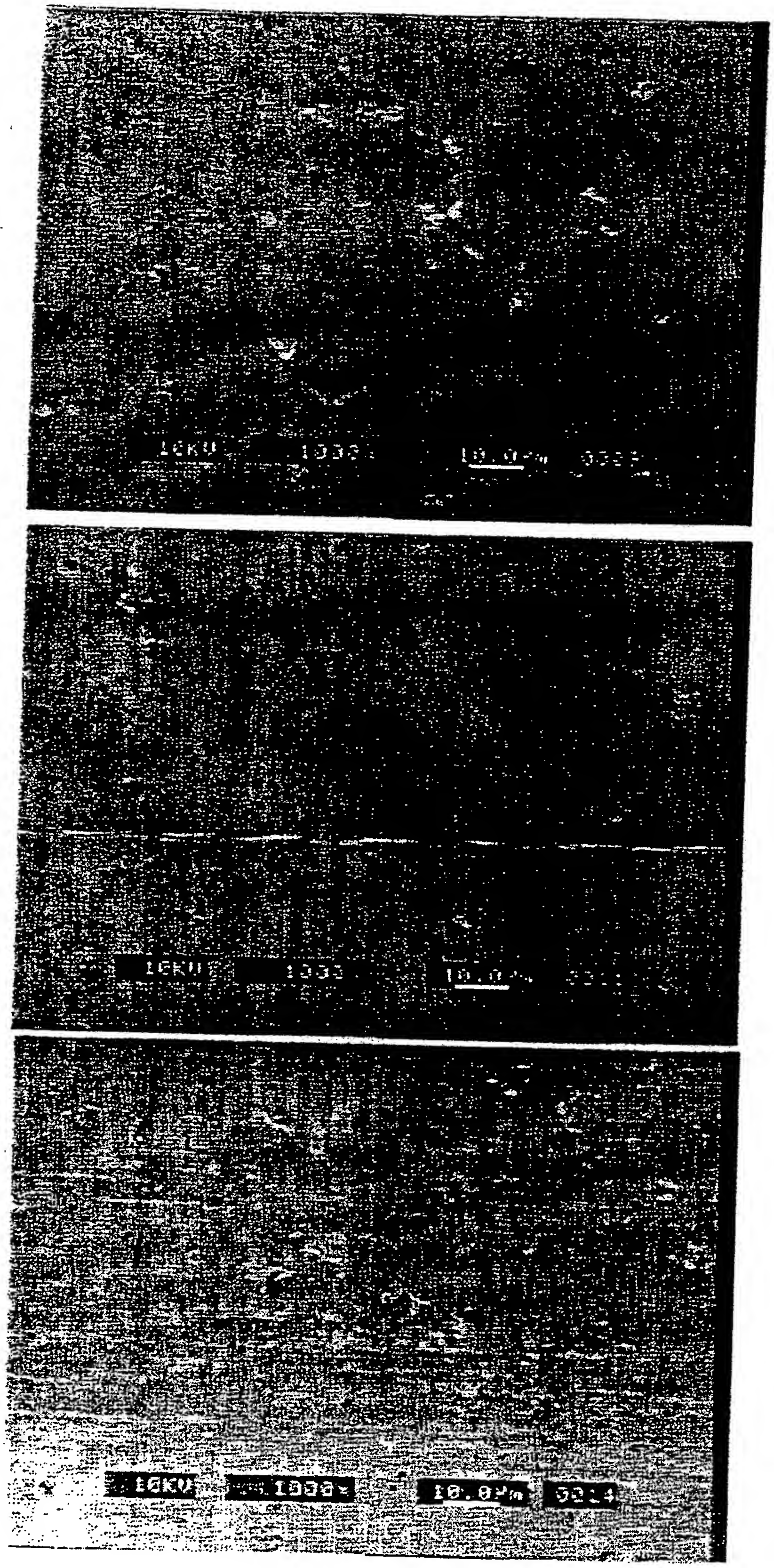


FIG. 10



BN
5 g/L

FIG. 11

10g/L

20g/L

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 2042

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	14 June 2000	Ziegler, H-J

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